BACKGROUND LIGHT MEASUREMENTS AT THE DUMAND SITE

T.Aoki, T.Kitamura, S.Matsuno, K.Mitsui, Y.Ohashi and A.Okada
Institute for Cosmic Ray Research, University of Tokyo, Tanashi, Japan
D.R.Cady, J.G.Learned, D.O'Connor, M.McMurdo and R.Mitiguy
Hawaii DUMAND Center, University of Hawaii, Honolulu, USA
M.Webster
Department of Physics, Vanderbilt University, Nashville, USA
C.Wilson
Department of Physics, Purdue University, Lafayette, USA
P.Grieder
Institute of Physics, University of Bern, Switzerland

Ambient light intensities at the DUMAND site, west of the island of Hawaii were measured around the one photoelectron level. Throughout the water column between 1,500m and 4,700m, a substantial amount of stimulateable bioluminescence is observed with a ship suspended detector. But non-stimulated bioluminescence level is comparable, or less than, K^{40} background, when measured with a bottom tethered detector typical of a DUMAND optical module.

1.Introduction The deep ocean environment may be an excellent location for the study of high energy cosmic ray muons and neutrinos. Great depths provide a good shield against low energy cosmic ray muons, and the vast quantities of sea water can supply sufficient target material to detect interactions of very high energy neutrinos. A very large deep underwater muon and neutrino detector(DUMAND) has been proposed[1)] and intensive feasibility studies have been performed. In the DUMAND project, very high energy muons and neutrinos are detected via the Cerenkov light emitted from secondary particles produced in their interactions within the sea water. However, even under deep ocean conditions there are some natural background light sources, Cerenkov light generated by radio isotopes and bioluminescent light by ocean inhabitants. We performed background light measurements by two different deployments, a ship suspended and a bottom tethered, and we have compared these two sets of data.

2.Apparatus and Experimental Procedures The instrument is self contained and powered by dry batteries. We used two 5" ϕ hemispherical photomultipliers(PMTs) mounted side by side in a glass housing of 17" ϕ. The space between PMTs and glass wall is filled with a transparent silicon jell to provide good optical contact. The high voltage power supplies and amplifiers for the PMTs are also mounted in the glass housing. The output signals from the PMTs are transmitted through cables to the data taking circuit contained in a separate metal housing.

The output signals from the PMTs are differentiated with time constant of 0.24 μsec and amplified with a gain of 100. The number of pulses exceeding a preset discriminator level is counted by a 16bit counter. Signals coincident within 200ns from the two PMTs are also counted. The discriminator level and the gate time are automatically changed under control of a microprocessor following a program stored in the ROM. There are 23 sampling steps of the discriminator level ranging from 32mV to 800mV, which cover the signal region from one to ten photoelectrons. The gate time is selected for each threshold betweem 10ms and 10sec in order to smooth out statistical fluctuations.

Electronics including PMTs are activated by a timer. The number of signal counts together with channel number and gate time are stored in a microcassette recorder and these data are analyzed after recovery of the instrument.

Measurement were done on a cruise with University of Hawaii's research vessel Kana Keoki, August 24-26 1984 at the DUMAND site, 30km off Keahole point of the Big Island of Hawaii. First, the instrument was lowered down to 4,500m at a speed of 30m/min, suspended by a wire. After staying 45min at 4,500m, the instrument was wound up with a rate of 50m/min stopping every 1,000m. The data taking scheme was programed such that data were taken while stopping at the depths of 4,500 3,500, 2,500 and 1,500m. Next, the instrument was permitted to free fall to the sea floor of 4,800m depth. The sensor was mounted 100m above the mooring which included timed and acoustically triggerable releases. Flotation was attached to the instrument package and a buoy with radio beacons and strobe lights was attached 50m above. The data taking program was the same as for the first case except for the fact that measurements were repeated four times at the same depth.

3.Results In Fig.1 count rates versus time interval of observation are plotted. The data is for PMT No.1 at the threshold voltage of 320mV. Data points marked 1,2,3 and 4 are for the ship suspended case and each corresponds to count rates at the depth of 1,500, 2,500, 3,500 and 4,500m, respectively. Data with mark F is for the bottom tethered experiments. In Fig.1 we also plotted dark noise data, with mark C, measured in the laboratory at 3°C. From Fig.1 we can see clear differences in count rates depending upon the method of deployment. The ship suspended rates change with time very much except for case 1, where count rates are too high to be fully resolved. In contrast, the bottom tethered rates are comparatively stable and their absolute rates are about an order of magnitude lower than the ship suspended ones. The data for PMT No.2 shows almost the same behavior as PMT No.1.

Fig.2 shows the integral pulse height spectra observed by PMT No.1. Symbols 1,2,3,4,F and C are same as in Fig.1. The ship suspended data fluctuate very much and show a complicated behavior, whereas the bottom tethered spectrum is rather smooth. From Fig.2 we can see that the free fall count rate(F) converges to that of laboratory rate(C) in the highest channels. This result indicates that signals of F come from very weak sources.

Though the time variation of the bottom tethered rates are weak compared to the ship suspended case, we do observe some time spikes in the bottom tethered data. Such signals appear in both PMTs at the same time. Fig.3 shows examples of the time structure of the spike signals. It appears as if their time structure can be expressed by an exponen-

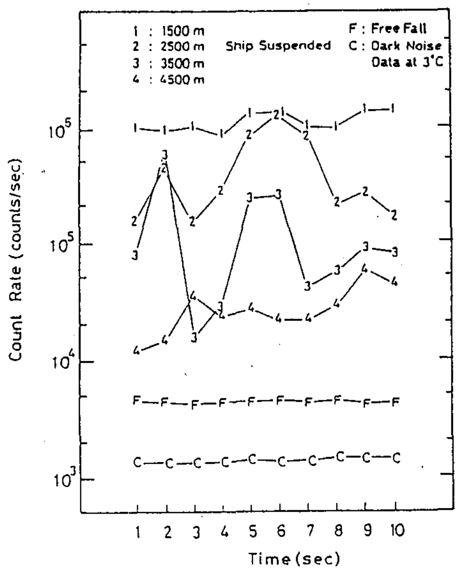

FIG. 1 Time Variation of Count Rate

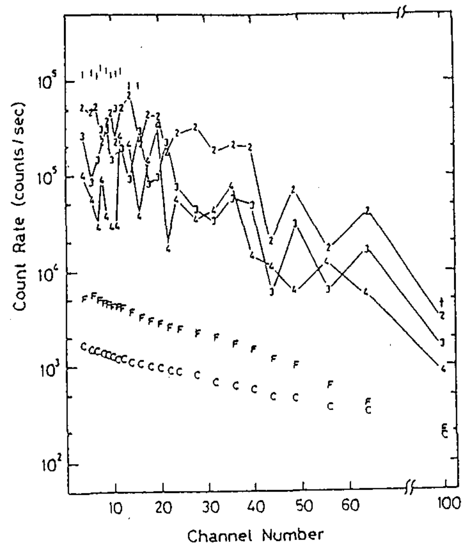

FIG. 2 Pulse Height Spectrum of Background

tial function with a time constant of $0.3 \sim 1.0$sec. The observed frequencies and time structures seem to coincide with the expected signals[2] in deep quiescent ocean basins. In the case of the ship suspended method, the signal rates are too high for any time structure analysis with such a long time constant.

To estimate the absolute flux of the measured background light, we calibrated the detection power of our optical sensor[3]. Results of calibration show that the photon fluxes observed by the two PMTs No.1 and No.2 agree very well for all depths. Fig.4 shows the absolute light intensity versus depth. Because the count rates of the ship suspended case fluctuate largely, we plotted the median value in Fig. 4. The intensity curve can be expressed as a function of depth x as $I = 3.72 \times 10^5 \exp(-x(m)/877)$ quanta/cm^2· sec, which is quite similar to $I = 2.008 \times 10^5 \exp(-x(m)/960)$ quanta/cm^2· sec given by H.Bradner et al[4].

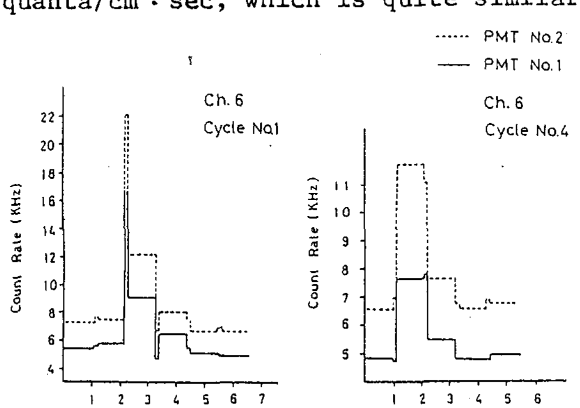

FIG. 3 Time Structure of Spike Signal

4.Discussions What is the origin of the differences in data sets for the two deployments? There are some reports[2),4)] on the observations of extensive stimulated bioluminescence in the deep ocean. The time dependence and depth dependence of our data also suggest it to be due to bioluminescence. It is well known that luminous species easily respond to physical and chemical stimulation. For the case of the ship suspended runs, the environment of inhabitants can be agitated by the motion of the instrument. Under these circumstances it is quite natural that the light intensity due to bioluminescence changes greatly with time. Futher, it is known that the planktonic biomass y can be expressed by the equation $y = a_5 x \exp(-kx)$, where x is the depth[5]. Our data in the depth dependence of the light intensity shows a similar behavior, which suggests that the photon flux data may reflect the amounts of organisms in the environment.

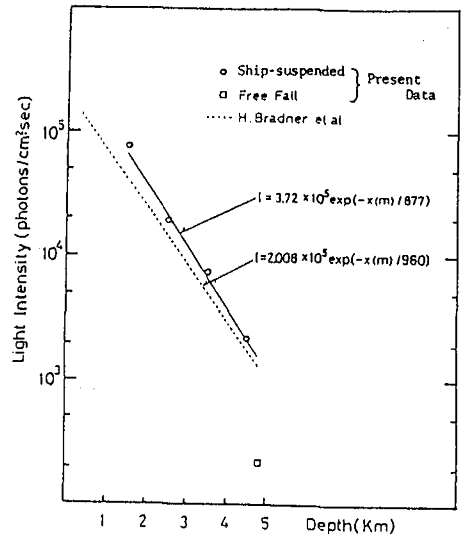

FIG. 4 Light Intensity Versus Depth

The mean value of the bottom tethered flux is 218^{+20}_{-60} cm$^{-2}\cdot$ sec^{-1}. For the bottom tethered case, the stimulation of luminous species is very weak. The cotribution of noticeable spike signals, which are considered to be due to such species, is only 6% of the total count rate. Several authors[6),7)] have calculated the photon flux due to Cerenkov light emitted by β-decay electrons from K^{40}. Their results scatter around 150 photons cm$^{-2}\cdot$ sec^{-1}. Considering the uncertainties of the energy loss process, light attenuation length and sensor detection efficiency assumed in the calculation, the expected value and our results are consistent with each other. Also, because Cerenkov light from individual K^{40} decays is quite feeble(typically 40 photons), this light will appear to the PMT as a single photon source[7)]. Our analysis of the pulse height spectra shows that the bottom tethered data does not contain large signals. From these results we conclude the main light source for the bottom tethered exposure is K^{40}.

In summation, we have found that the background at the DUMAND site is tolerable level for the DUMAND otical sensors.

References

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